

## §5. Development of High Power Sub-terahertz Pulse Gyrotron

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### i) Introduction

Development of a gyrotron suitable to a power source of collective Thomson scattering (CTS) diagnostics is a challenging task. At the moment, fusion grade gyrotrons with frequencies around 100 GHz are used [1, 2]. However, electromagnetic waves with these frequencies suffer from strong plasma dispersion effects. Use of a sub-terahertz gyrotron will resolve these problems.

Development of a high power sub terahertz pulse gyrotron is under way with collaboration between FIR-FU and NIFS for application to CTS from a high density plasma in LHD [3]. As the first step, a second harmonic gyrotron of demountable type was fabricated. Experiments have proved single mode oscillation of second harmonic modes and oscillation power of 50 kW at 350 GHz and about 40 kW at 390 GHz [4]. These values are the world records as second harmonic oscillation in the frequency range around 400 GHz.

### ii) Experiment with a sealed off gyrotron

A gyrotron of sealed-off type was manufactured as the second step. This gyrotron also works at the second harmonic frequency. It has the same cavity dimensions and the electrodynamic design as those of the first step gyrotron. Then, we can examine the effects of sealing off. Operation of the gyrotron is in pulse mode. The pulse length is several microsecond and the repetition rate is less than 10 Hz.

A group of second harmonic oscillation modes such as the  $TE_{3,7}$ ,  $TE_{1,8}$  and  $TE_{17,2}$  modes has been adopted in the second step gyrotron because these modes are further isolated from the competing fundamental  $TE_{4,3}$  mode than the  $TE_{8,5}$  mode used in the first step gyrotron. Figure 1 shows the oscillation intensity measured with a pyroelectric detector as a function of the magnetic field strength  $B_c$  at the cavity for the case of the beam voltage  $V_k = 50$  kV and the beam current  $I_b = 4$  A. The oscillation mode turns successively from the  $TE_{3,7}$  mode to the  $TE_{8,5}$  mode with increasing  $B_c$ . Each mode has been identified from frequency measurement with a Fabry-Perot interferometer and a heterodyne receiver system. The  $TE_{3,7}$ ,  $TE_{1,8}$  and  $TE_{17,2}$  modes are indeed free from mode competition with the  $TE_{4,3}$  mode. However, the  $TE_{8,5}$  mode often oscillates simultaneously with the  $TE_{4,3}$  mode for large  $V_k$  and  $I_b$ . Among these modes, the  $TE_{1,8}$  mode is strongest in a wide range of  $V_k$  and  $I_b$ .

The output power  $P$  was measured with a water load installed just outside of the vacuum window. Figure 2 plots

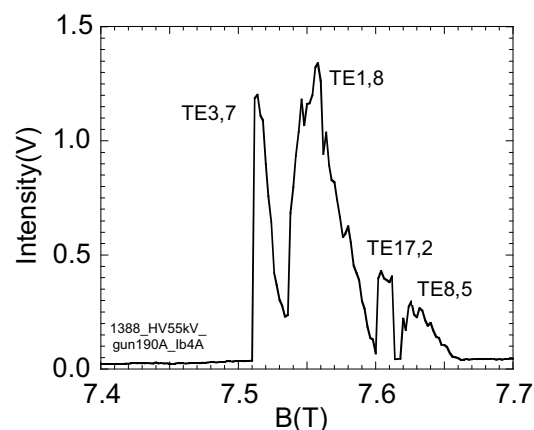


Fig. 1. Oscillation intensity is plotted as a function of the magnetic field strength at the cavity. Labels near each peak indicate the oscillation mode.

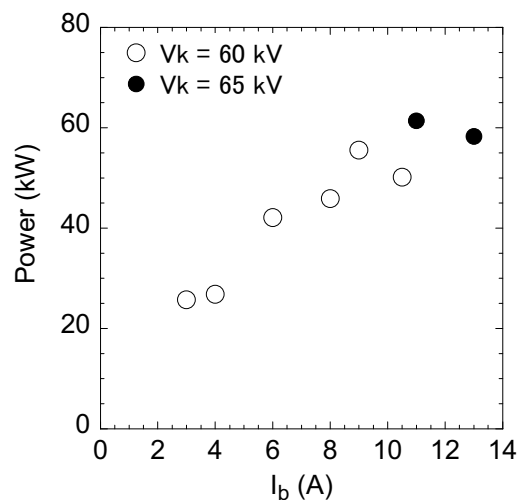


Fig. 2. Output power measured with a water load as a function of the beam current.

$P$  of the  $TE_{1,8}$  mode as a function of  $I_b$ . The open circles represent  $P$  for  $V_k = 60$  kV and the closed ones stand for  $P$  for  $V_k = 65$  kV. Each data point was obtained with careful adjustment of the operation conditions such as the anode voltage and the current of the auxiliary coils installed at the cathode region. These parameters change the radius and the pitch factor of the electron beam at the entrance of the cavity. The output power increases with  $I_b$  and attains at 57 kW for  $V_k = 60$  kV but slightly decreases at  $I_b$  larger than 9 A. This was likely due to deterioration of the beam quality at large  $I_b$ . Then, operation voltage was increased to 65 kV and further increase in  $P$  was obtained. It has reached 62 kW at  $I_b = 11$  A. However, decrease in  $P$  at larger  $I_b$  still remains.

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- [2] Nielsen, S. K. et al., Nucl. Fusion **51** (2011) 063014.
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- [4] Notake, T. et al., Phys. Rev. Lett. **103**, (2009) 225002.